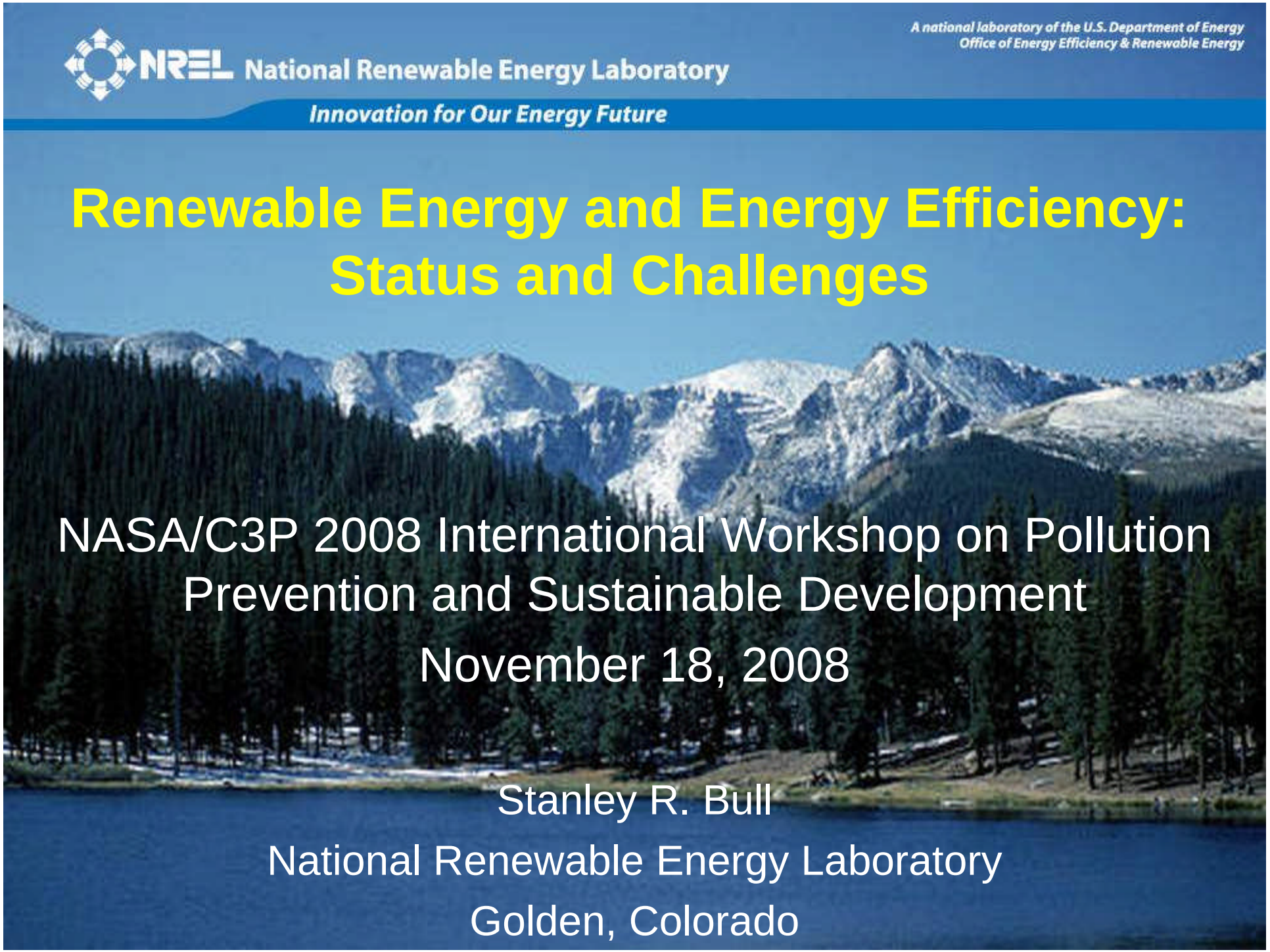


Renewable Energy and Energy Efficiency: Status and Challenges

NASA/C3P 2008 International Workshop on Pollution Prevention and Sustainable Development

November 18, 2008

Stanley R. Bull

National Renewable Energy Laboratory

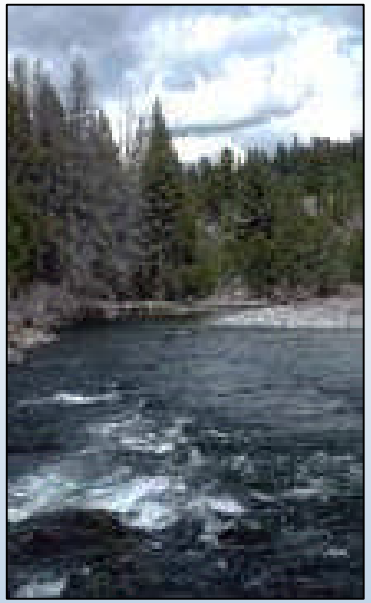
Golden, Colorado

Energy Challenges are Enormous

Energy Security and Reliability

Economic Growth

Natural Disasters



Environmental Impact

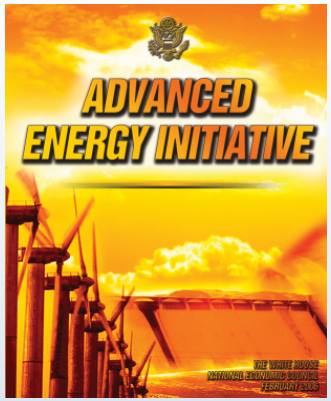
Mounting Evidence


TOM'S SHELL
Self Serve
Cash or Credit
Regular
ARM 9
Plus
LEG 9
Premium
First 9 Born

Getting to “Significance” Involves…

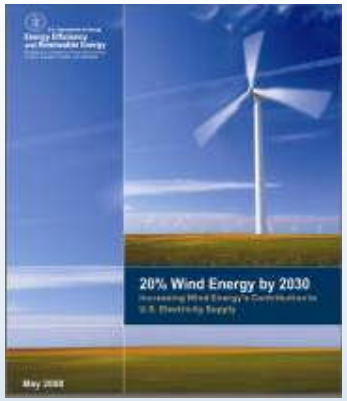
Source: NREL

Setting the Bar Higher – Gigawatt-Scale Renewables



Solar Vision

10% U.S. electricity by 2025



Wind Vision

20% U.S. electricity by 2030

Energy Independence & Security Act 2007

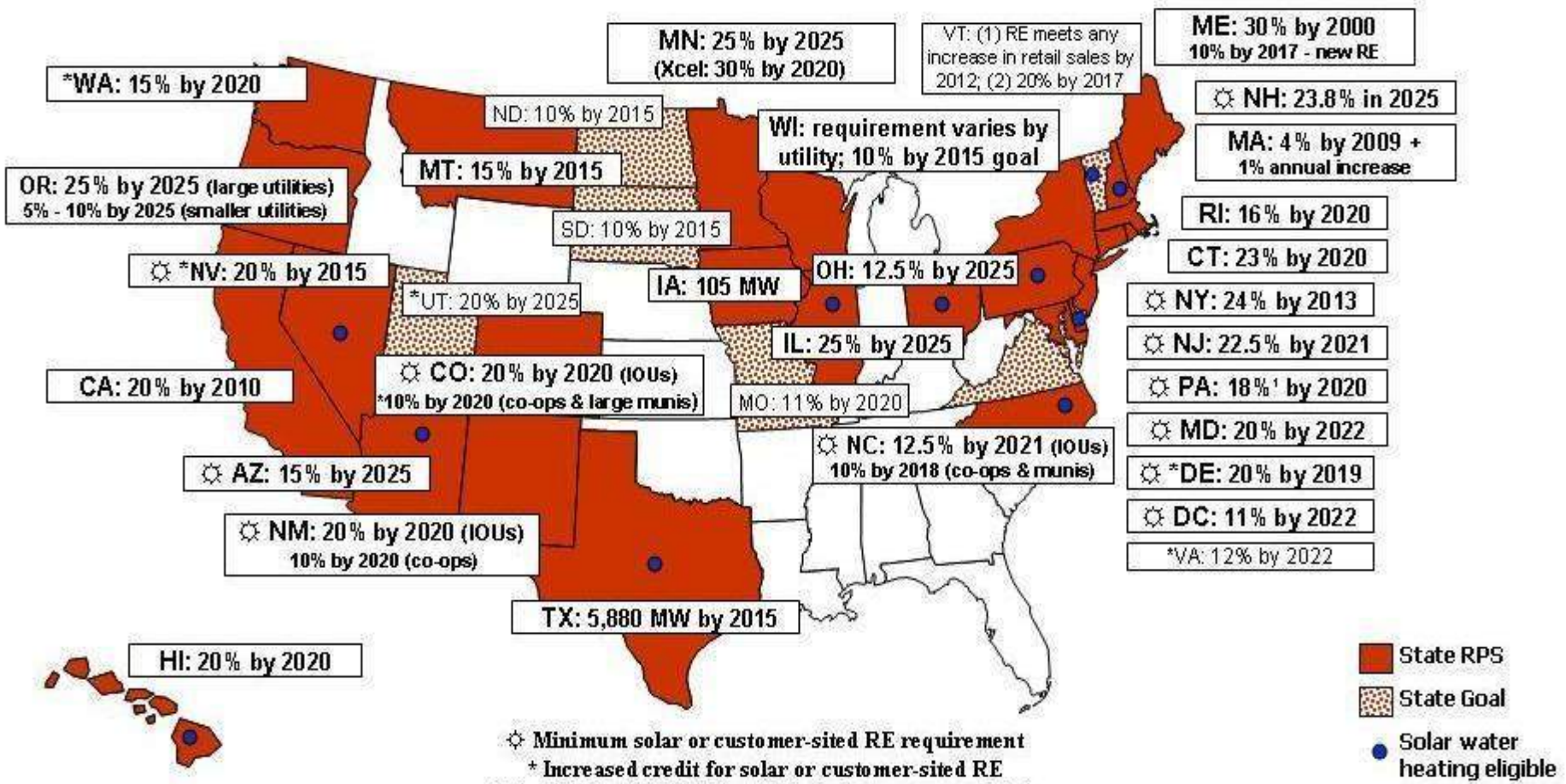
36 billion gallons of renewable fuels by 2022

Requires investment in new infrastructure:

- Overall in U.S. = $2 trillion
- Worldwide = $22 trillion
  - Biofuels
  - Wind
  - Solar

} $2 trillion (est.)

State Renewable Portfolio Standards

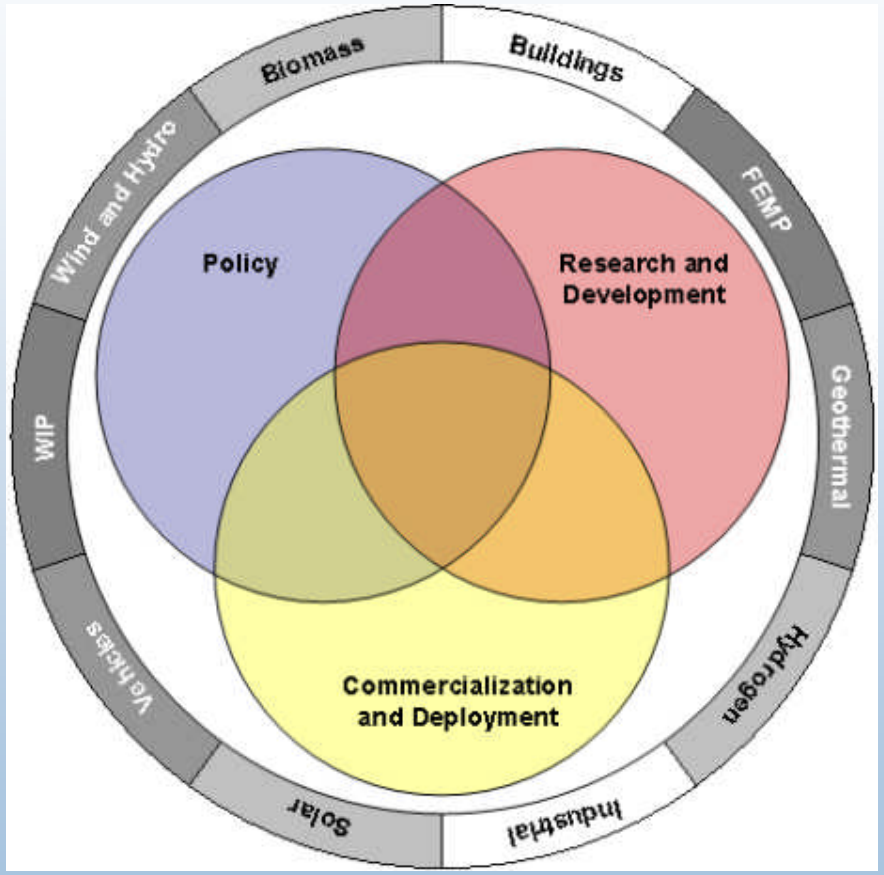


Our applied science and clean energy technology portfolio is dedicated to accelerating market penetration of America's abundant, secure, affordable and clean renewable energy and energy efficiency technologies.

Power Generation
- Solar
- Wind
- Hydropower
- Geothermal

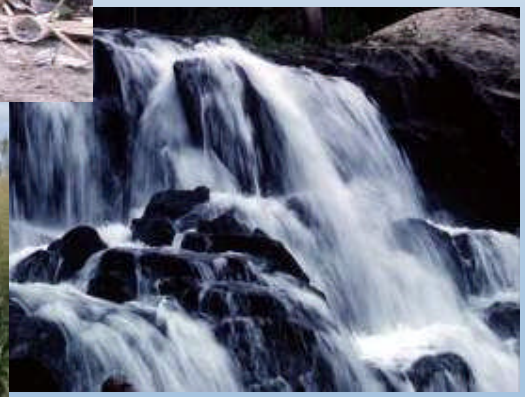
Fuels & Vehicles
- Biomass/Biofuels
- Hydrogen
- Vehicle Technologies
  - o Batteries

Energy Efficiency
- Buildings Technologies
- Industrial Technologies
- Weatherization
- Federal Energy Management

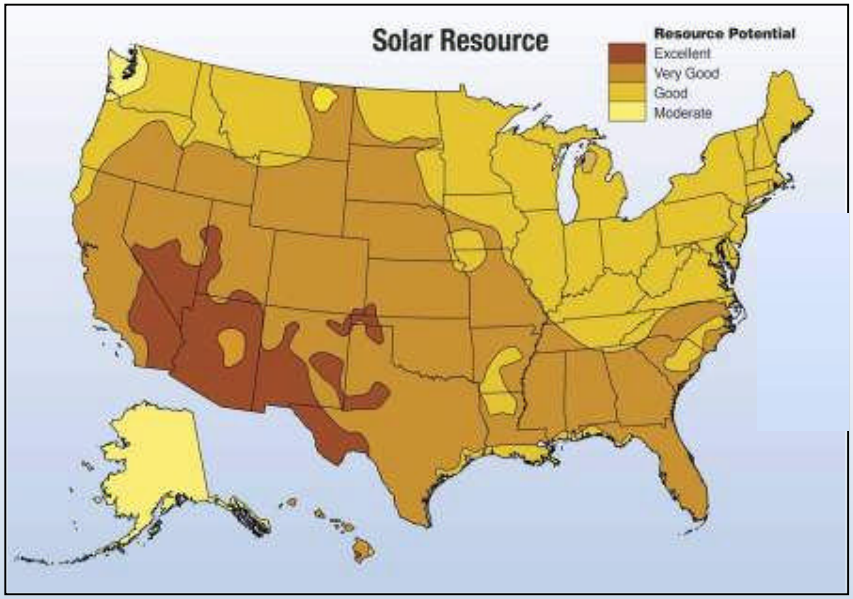


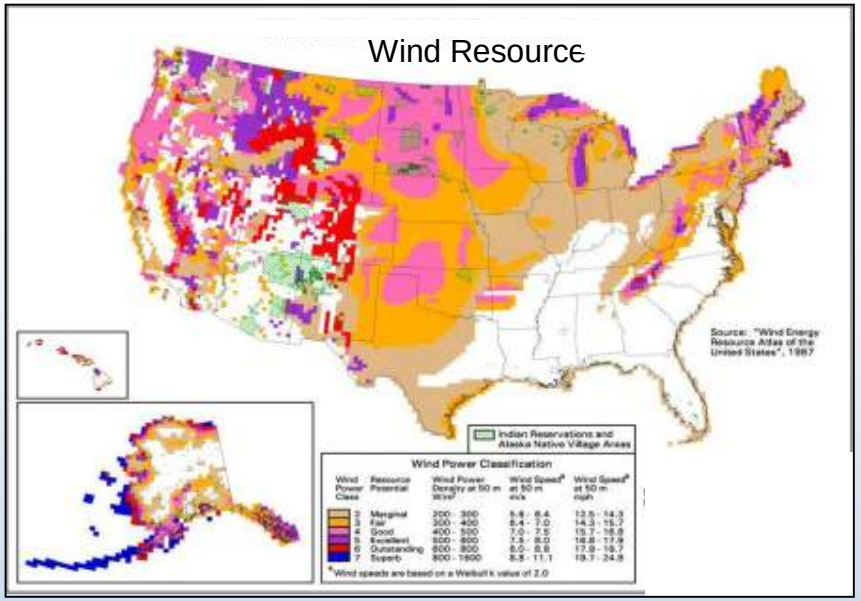
The President's Advanced Energy Initiative aims to change the way we power our homes, business, and automobiles.

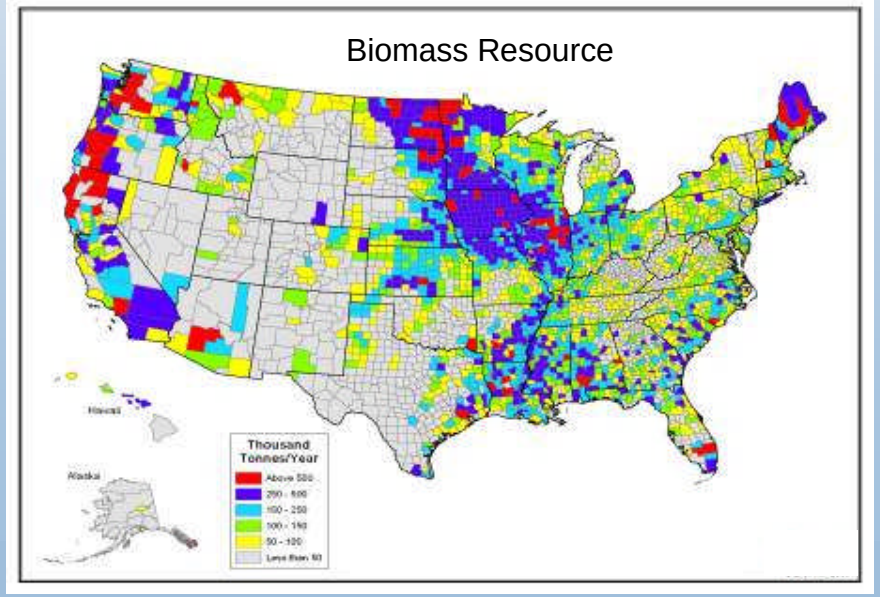
Renewable Energy

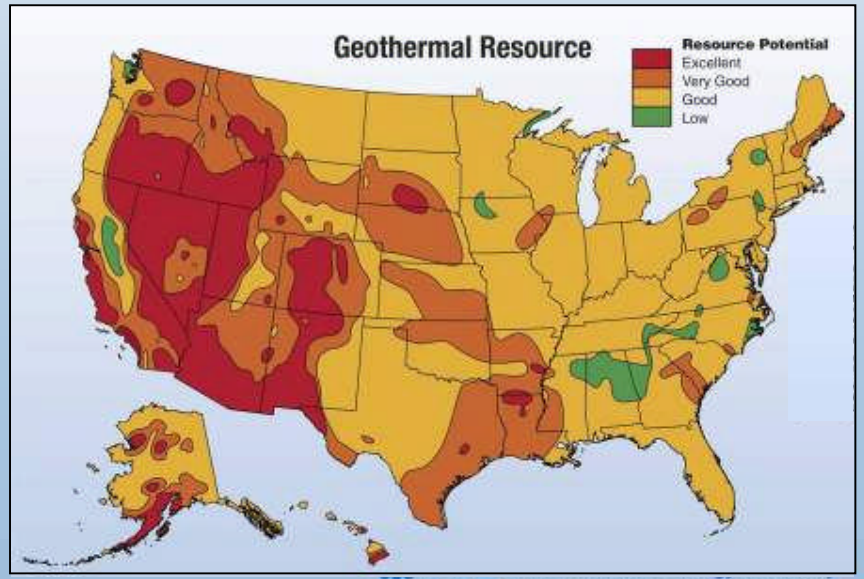


U.S. Renewable Energy Resources



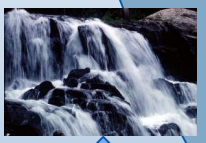






Renewable Energy Pathways from the Resource to the End-User



Renewable Resources

- Wind
- Solar
- Biomass
- Geothermal
- Hydroelectric
- Ocean



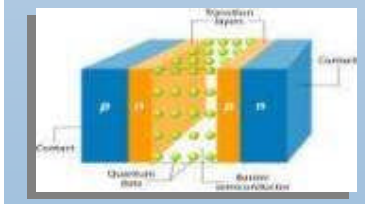


Efficient Energy Use

- Buildings
- Industry
- Transportation

Energy Delivery and Storage

- Electricity Transmission & Distribution
- Alternative Fuels
- Hydrogen Delivery and Storage

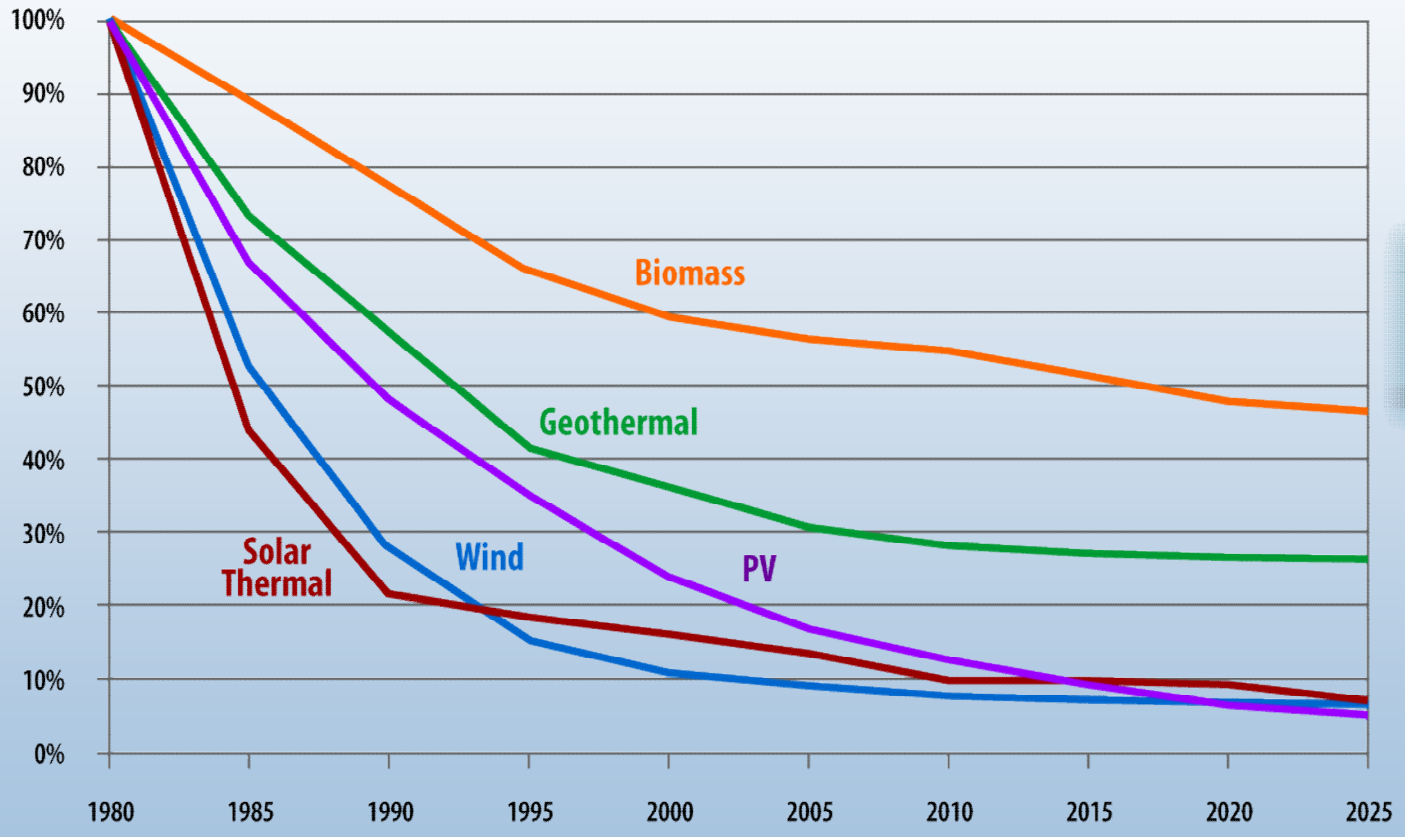


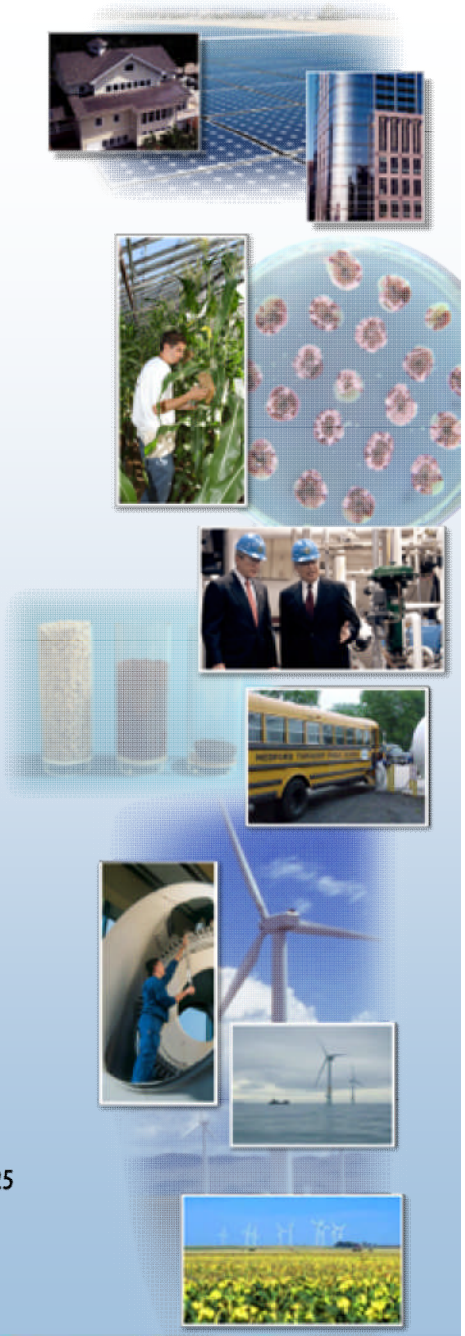

Foundational Science

Applied Science

NREL National Renewable Energy Laboratory

Past Investments Have Yielded Impressive Cost Reductions





Renewable Power Solutions

- Accelerating high penetration of wind and solar power by addressing the key integration and inter-connection challenges of intermittency and variability.*
- Fostering greater dispatchability and response for solar and wind by developing and evaluating energy storage solutions.**
- Enabling wind power to produce up to 20% of the Nation's electricity by improving the performance of turbines, blades, and related components.
- Continuing Solar America Initiative to lower cost of photovoltaics to reach unsubsidized grid parity by 2015.
- Establishing demonstration sites for Enhanced Geothermal Systems and evaluating reservoir creation techniques.
- Benchmark testing of leading ocean, wave, and tidal technologies.

*(Cooperative programming with Office of Electricity Delivery and Energy Reliability (OE))

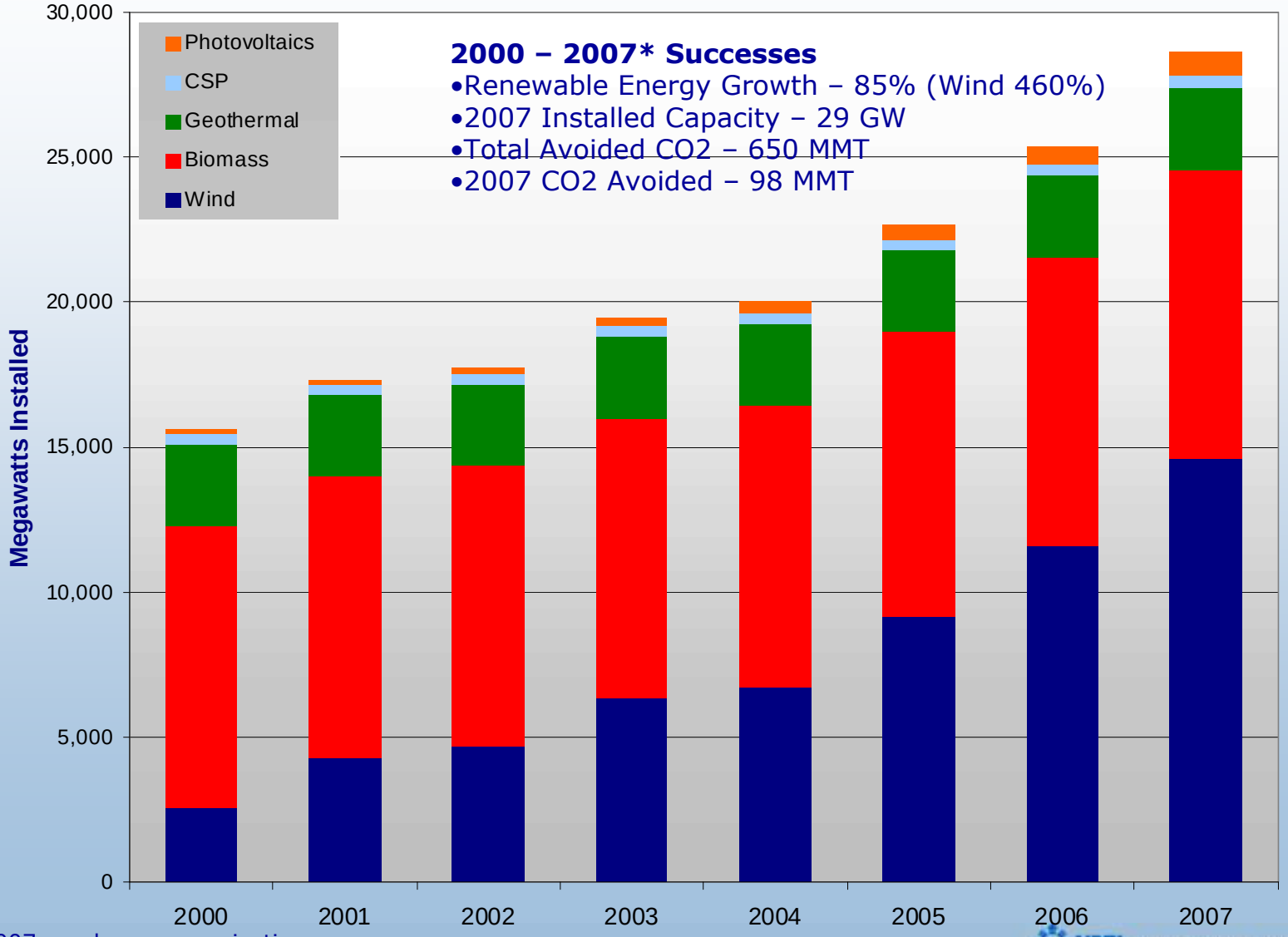
**(Joint program with OE and Office of Science)

U.S. RE Capacity Rapidly Expanding

Percent of Annual New Capacity			
	2004	2005	2006
Renewables	2%	11%	22%
Natural Gas	72%	85%	72%
Coal	2%	2%	5%
Petroleum	1%	1%	1%
Dual Fired	22%	0%	0%
Other*	0%	1%	0%

Source: EIA

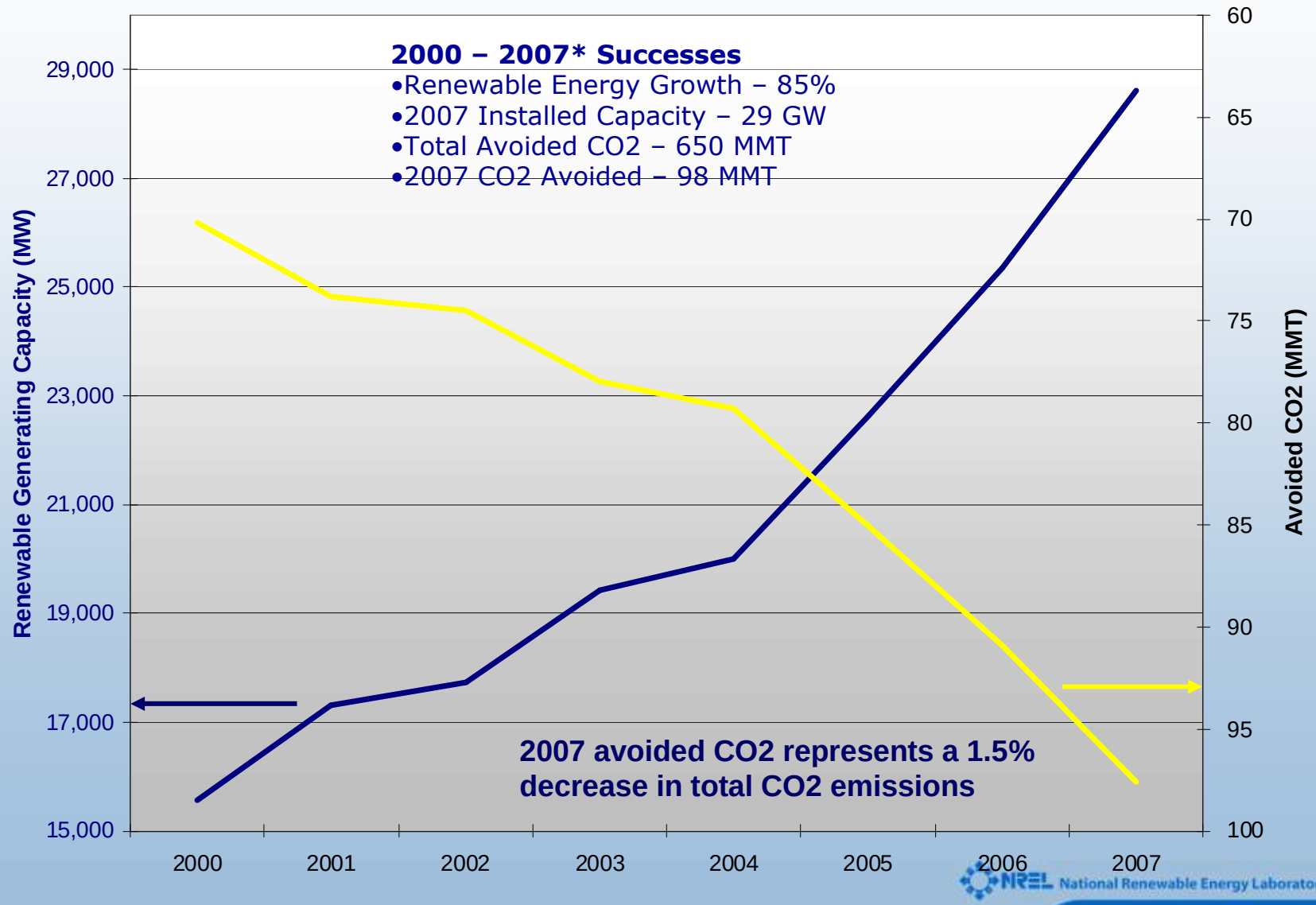
U.S. Renewable Electricity Capacity



*All 2007 numbers are projections.

Source: EIA

U.S. Renewable Generation Capacity and Resulting CO_2 Avoided

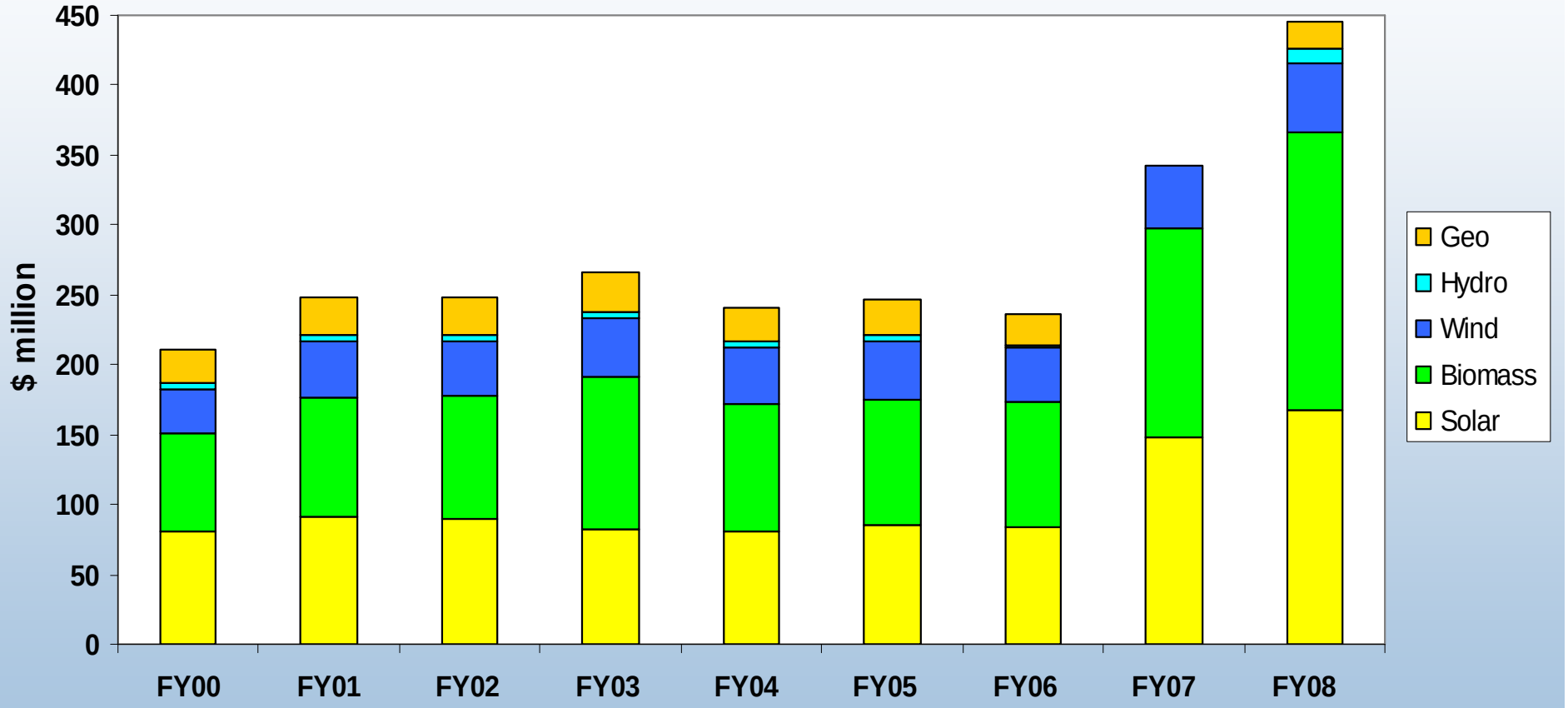


NREL National Renewable Energy Laboratory

*All 2007 numbers are projections.

Sources: EIA

U.S. Renewable Energy R&D Budget

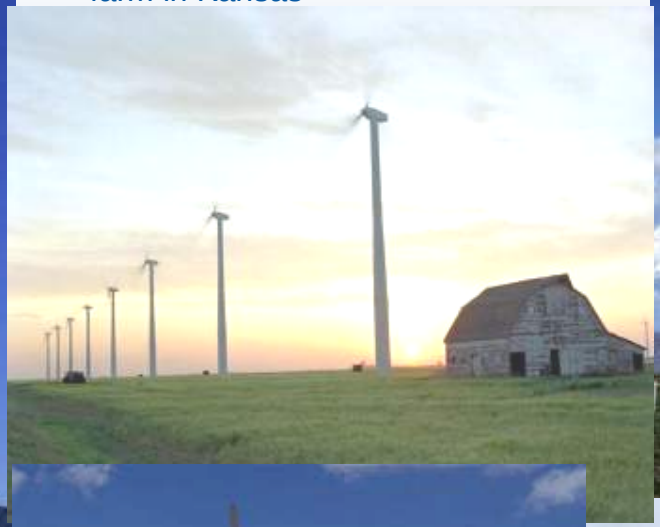


Wind Energy

GE Wind's 1.5 megawatt wind turbine installed in Tehachapi, California

Vestas V-47 Turbines on wind farm in Kansas

11193



Dyess Air Force Base, Texas (near Abilene)

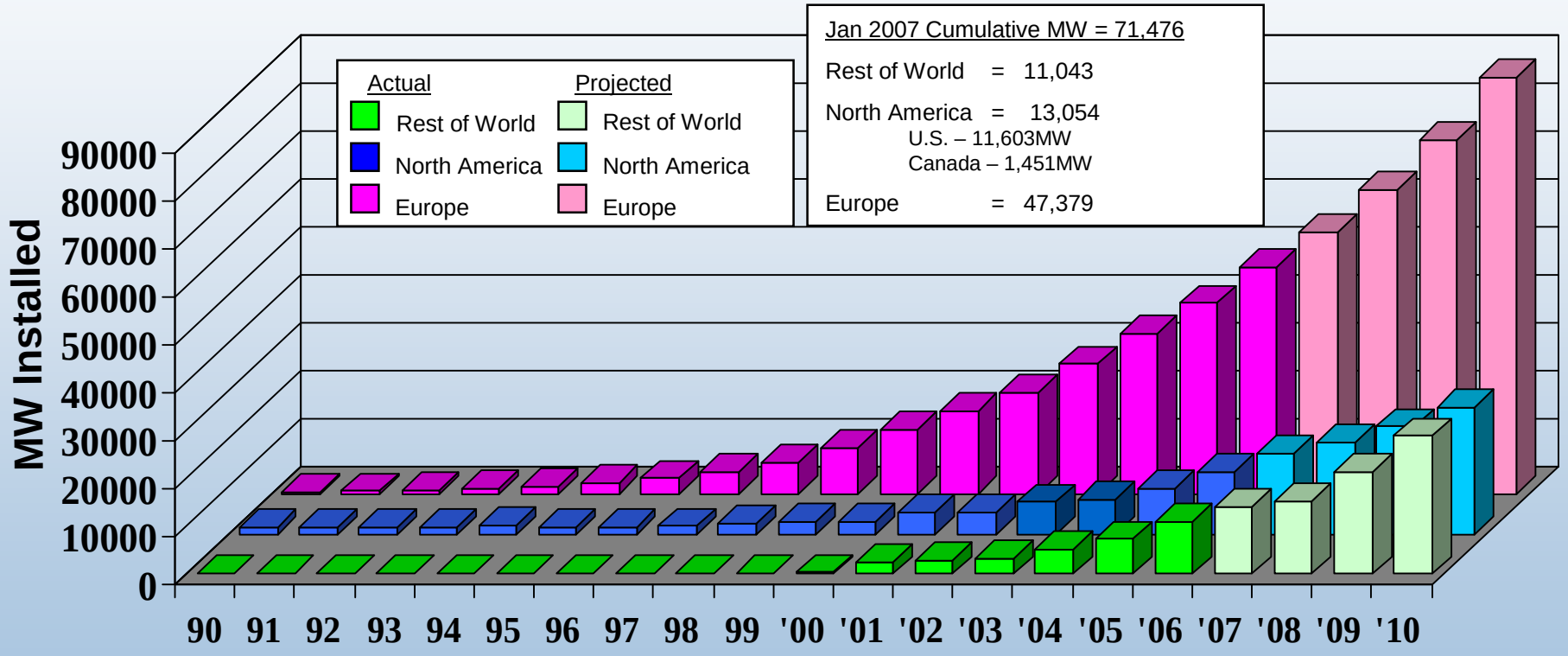
Brazilian hybrid power system

04824

00263

Palm Springs, CA, wind farm

Growth of Wind Energy Capacity Worldwide

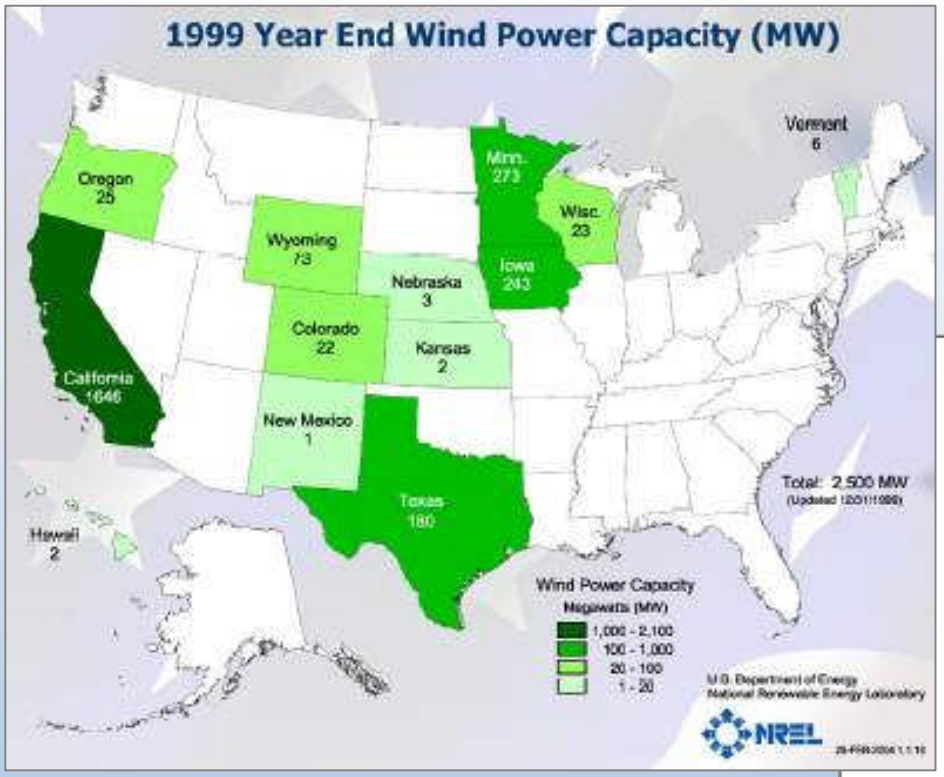


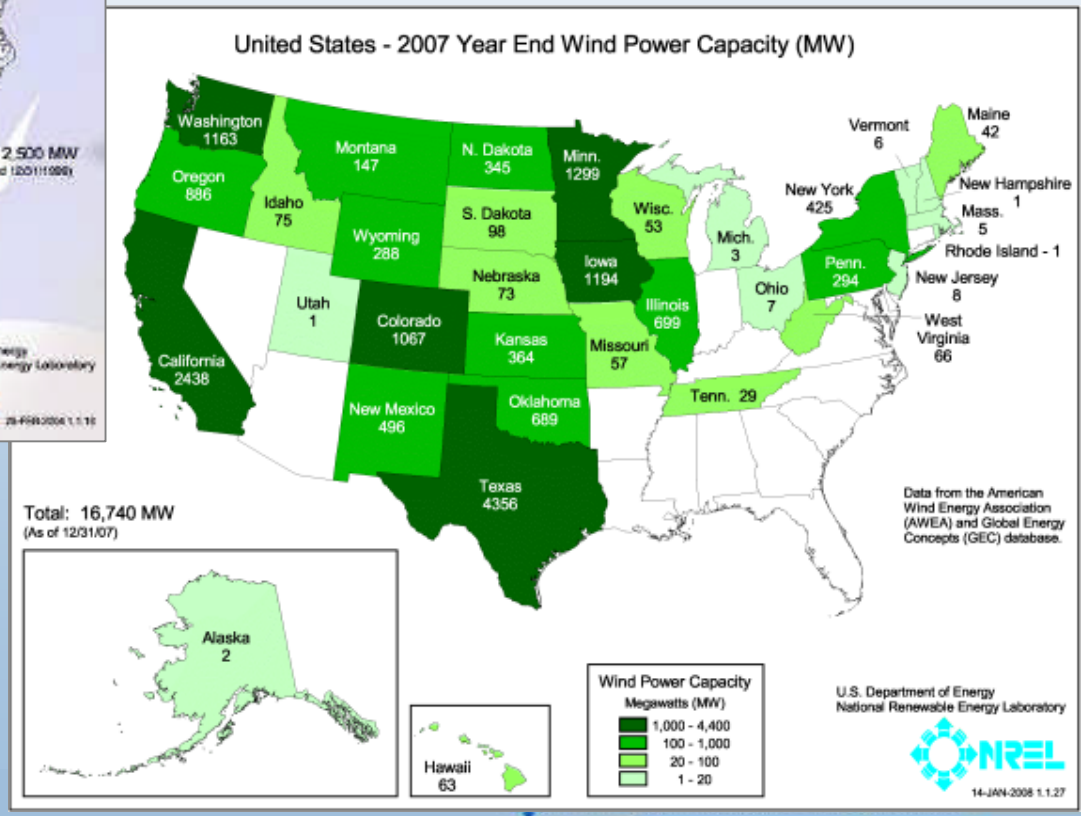
Sources: BTM Consult Aps, March 2005
Windpower Monthly, January 2007
*NREL Estimate for 2007


GE WindEnergy
3.6 MW Turbine
Boeing 747-200
Arklow Banks Windfarm
The Irish Sea
Photo: R. Thresher

Installed Wind Capacity

1999 – Dec 2007*





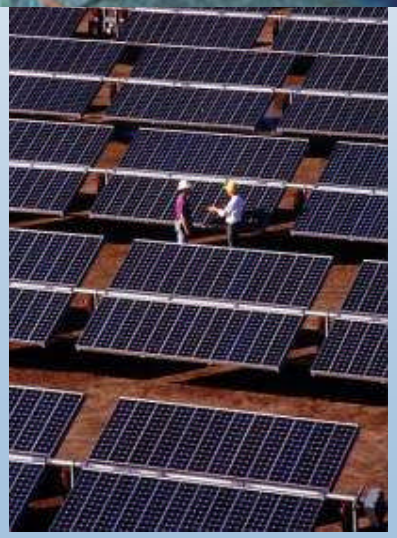
*Preliminary data

Solar Energy

PV roofing shingles

PV panels

Indo-US Cooperative
PV Project

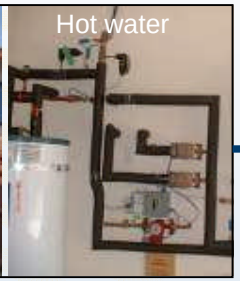


210 kW PV system at
SMUD's Hedge substation

Solargenix 64 MW
solar plant near
Boulder City, Nevada

Applications of Solar Heat and Electricity

Solar Thermal



Photovoltaics (PV)

Concentrating Solar Power (CSP)

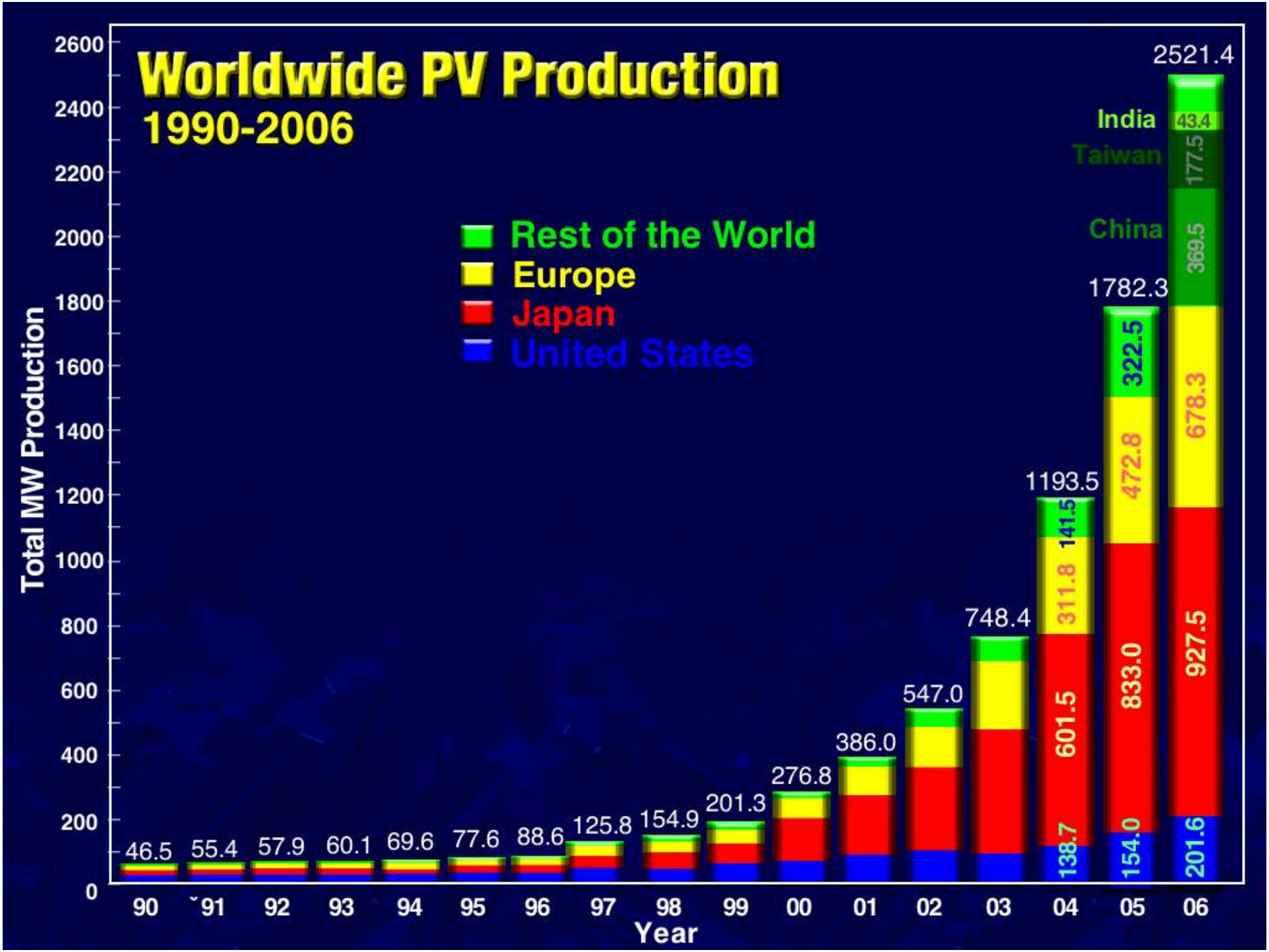
Distributed Generation, on-site or near point of use

Centralized Generation, large users or utilities

Transportation

Residential & Commercial Buildings

Industrial

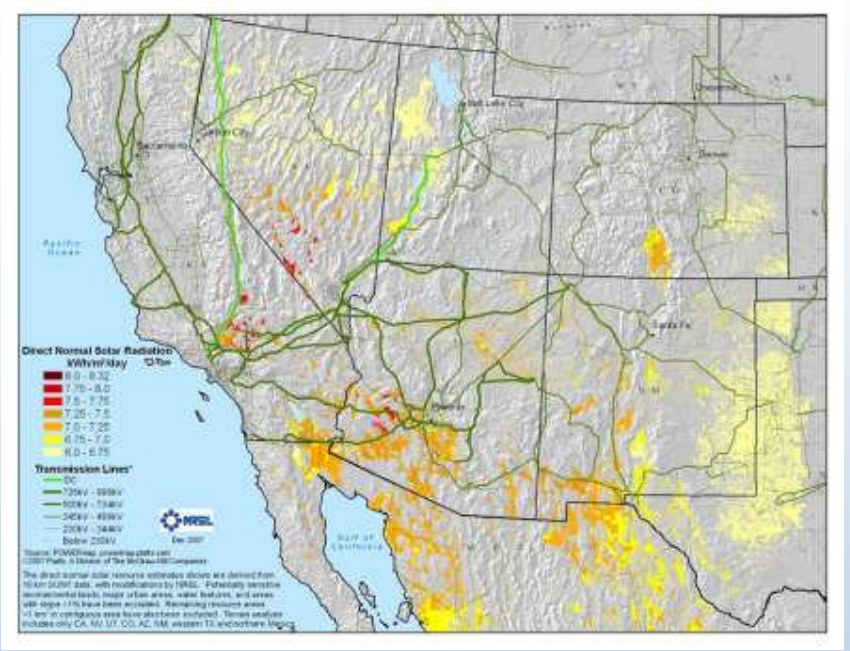

Worldwide PV Production
1990-2006
Rest of the World
Europe
Japan
United States
India
Taiwan
China
Total MW Production
Year
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
46.5
55.4
57.9
60.1
69.6
77.6
88.6
125.8
154.9
201.3
276.8
386.0
547.0
748.4
1193.5
1782.3
2521.4
138.7
601.5
311.8
141.5
154.0
833.0
472.8
322.5
201.6
927.5
678.3
369.5
177.5
43.4

Typical Business Rooftop PV Application

64 MWe Solargenix Parabolic Trough Plant – Nevada Solar 1

Resulting CSP Resource Potential

State	Land Area (mi^2)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	13,613	1,742,461	4,121,268
CA	6,278	803,647	1,900,786
CO	6,232	797,758	1,886,858
NV	11,090	1,419,480	3,357,355
NM	20,356	2,605,585	6,162,729
TX	6,374	815,880	1,929,719
UT	23,288	2,980,823	7,050,242
Total	87,232	11,165,633	26,408,956



The table and map represent land that has no primary use today, exclude land with slope > 1%, and do not count sensitive lands.
Solar Energy Resource ≥ 6.0
Capacity assumes 5 acres/MW
Generation assumes 27% annual capacity factor

Current total nameplate capacity in the U.S. is 1,000GW w/ resulting annual generation of 4,000,000 GWh

Geothermal Energy

00412

Power production from concentrated brines

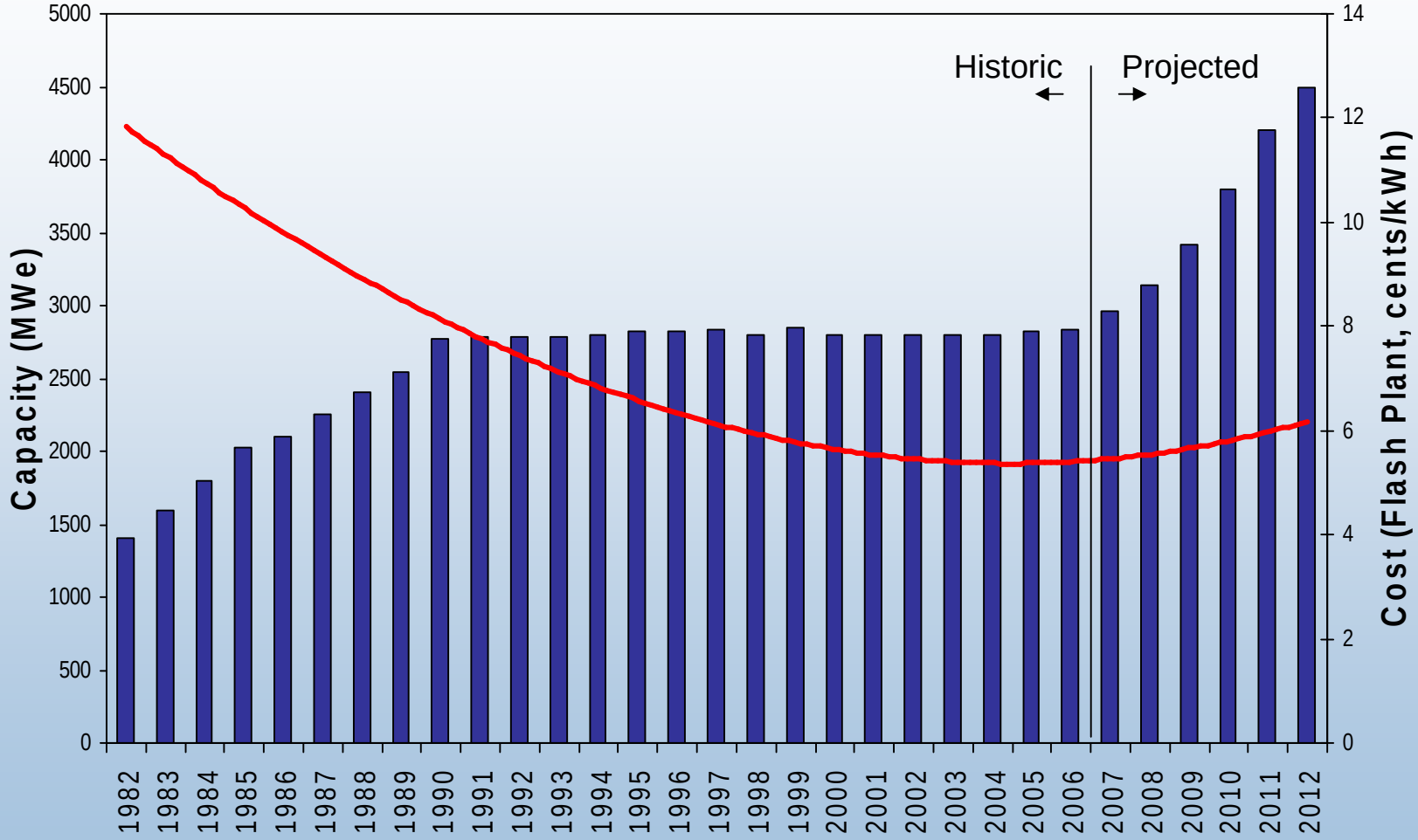
Geothermal power plant at The Geysers

00060

03694

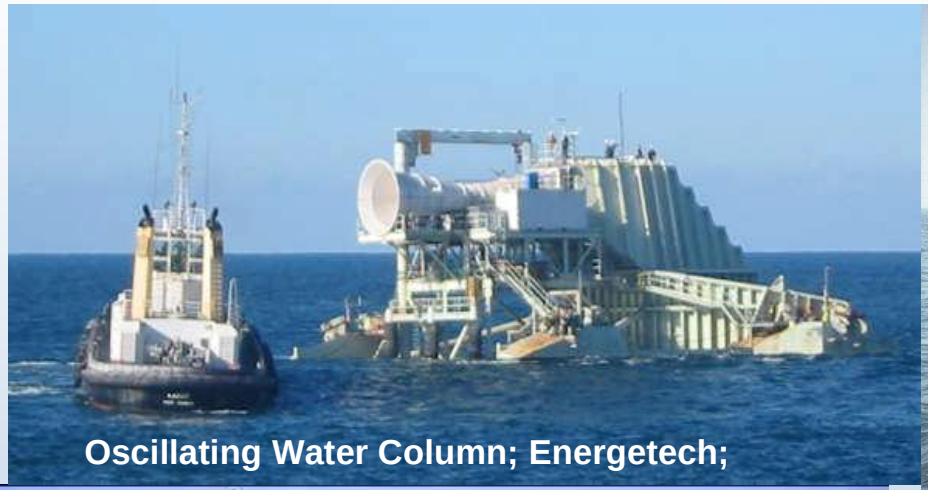
Heat exchangers and circulation pumps

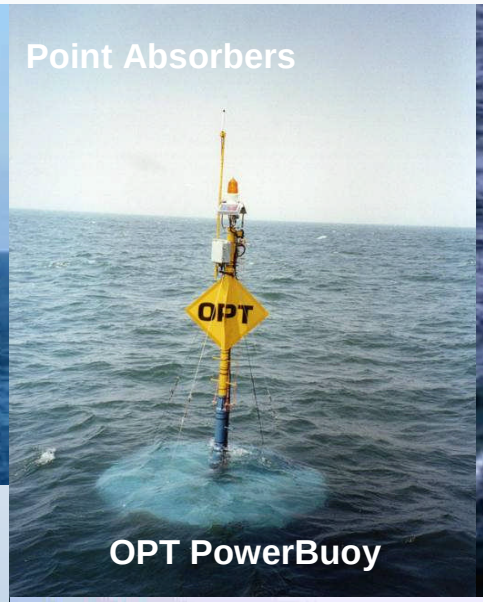
U.S. Geothermal Capacity



Projections of installed capacity based on documented projects in various stages of development (GEA, 2006)

Wave Technology Examples

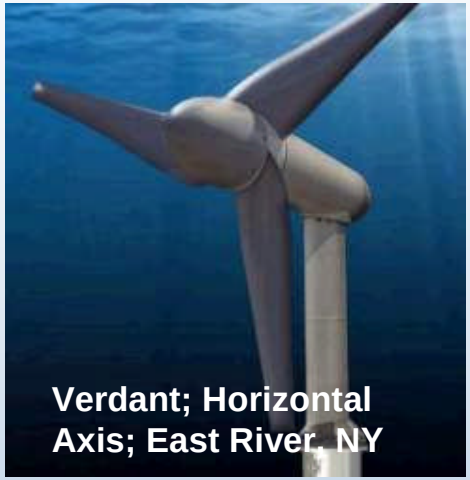

Oscillating Water Column; Energetech;




Attenuator; OPD Pelamis


Overtopping; Wave Dragon

Ocean Tidal & Current Technology

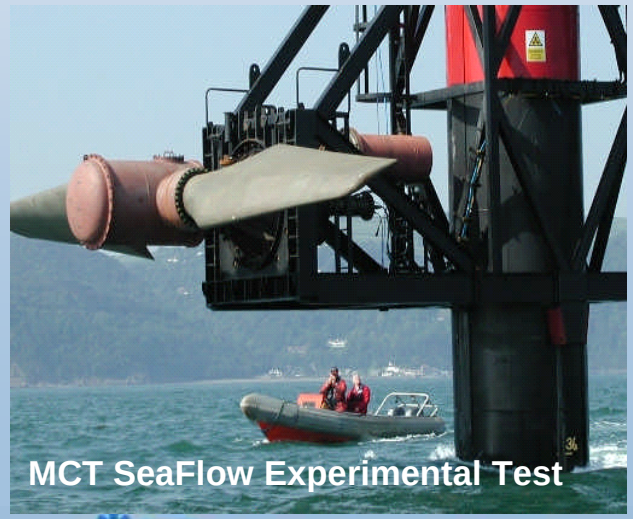

Verdant; Horizontal Axis; East River, NY


Gorlov Helical Vertical Axis; Merrimack River,


Hydro; Open Center Turbine; Gulf Stream


Lunar Energy, Rotech Tidal Turbine

Underwater Electric Kite; Merrimack River,


MCT SeaFlow Experimental Test

Advanced Fuels and Vehicles Solutions

- Advancing essential RD&D projects to achieve cost competitive, commercial scale cellulosic ethanol production by 2012, to meet the Renewable Fuels Standard in the Energy Independence and Security Act.
- Accelerating RD&D on lithium-ion batteries, plug-in hybrids, and drive-train electrification to diversify and make our nation's vehicles more efficient to reduce petroleum dependency.
- Continuing to research and develop critical hydrogen technologies that enable near-term commercialization pathways.
- Consolidation of technology validation for fuel infrastructure and vehicle testing; safety and codes & standards; and supporting education activities to accelerate the full portfolio of fuel and vehicle solutions to the market.

Biomass Energy

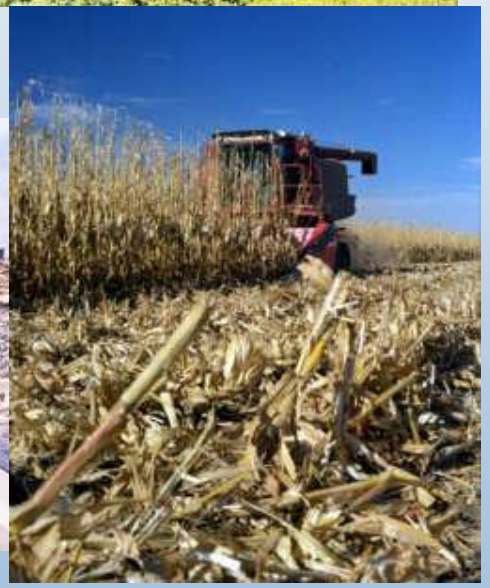
Wood chips

Switch grass

Poplars

Fats and Oils

Municipal solid waste



Corn Stover

The New Bio-Industry

Biomass Feedstock

– Trees
– Grasses
– Agricultural Crops
– Agricultural Residues
– Animal Wastes
– Municipal Solid Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Combustion
- Co-firing

USES

Fuels:
– **Ethanol**
– **Renewable Diesel**

Power:
– **Electricity**
– **Heat**

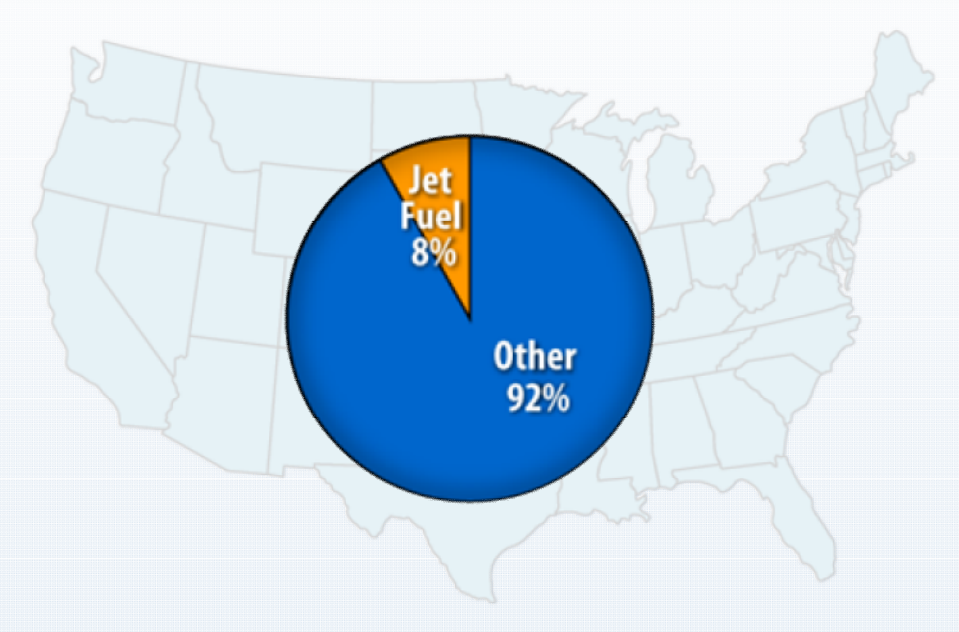
Chemicals
– **Plastics**
– **Solvents**
– **Chemical Intermediates**
– **Phenolics**
– **Adhesives**
– **Furfural**
– **Fatty acids**
– **Acetic Acid**
– **Carbon black**
– **Paints**
– **Dyes, Pigments, and Ink**
– **Detergents**
– **Lubricants**
– **Etc.**

Food and Feed and Fiber

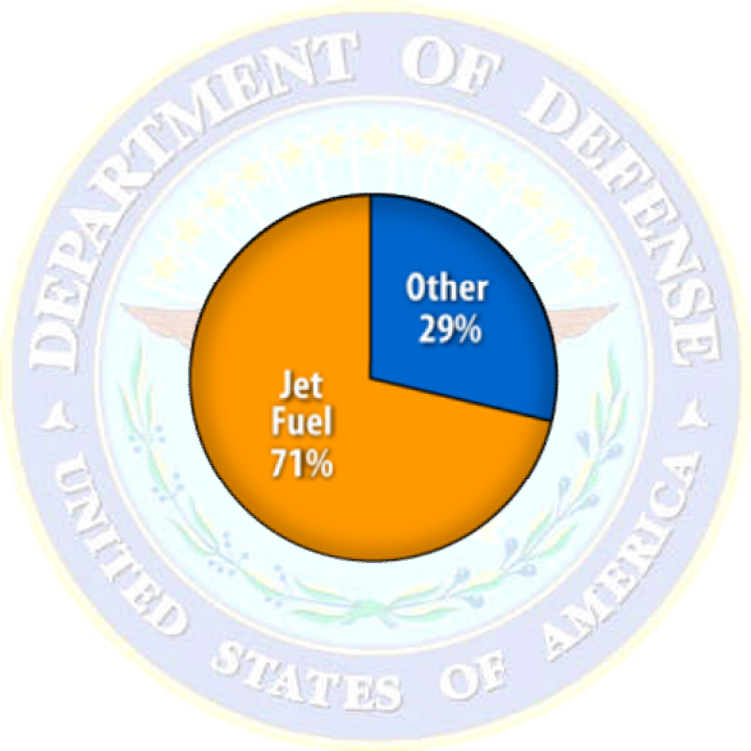
… and new concepts from plants to products

Military Fuel Mix is Very Different from Commercial Fuel Mix

Commercial US Fuel Consumption



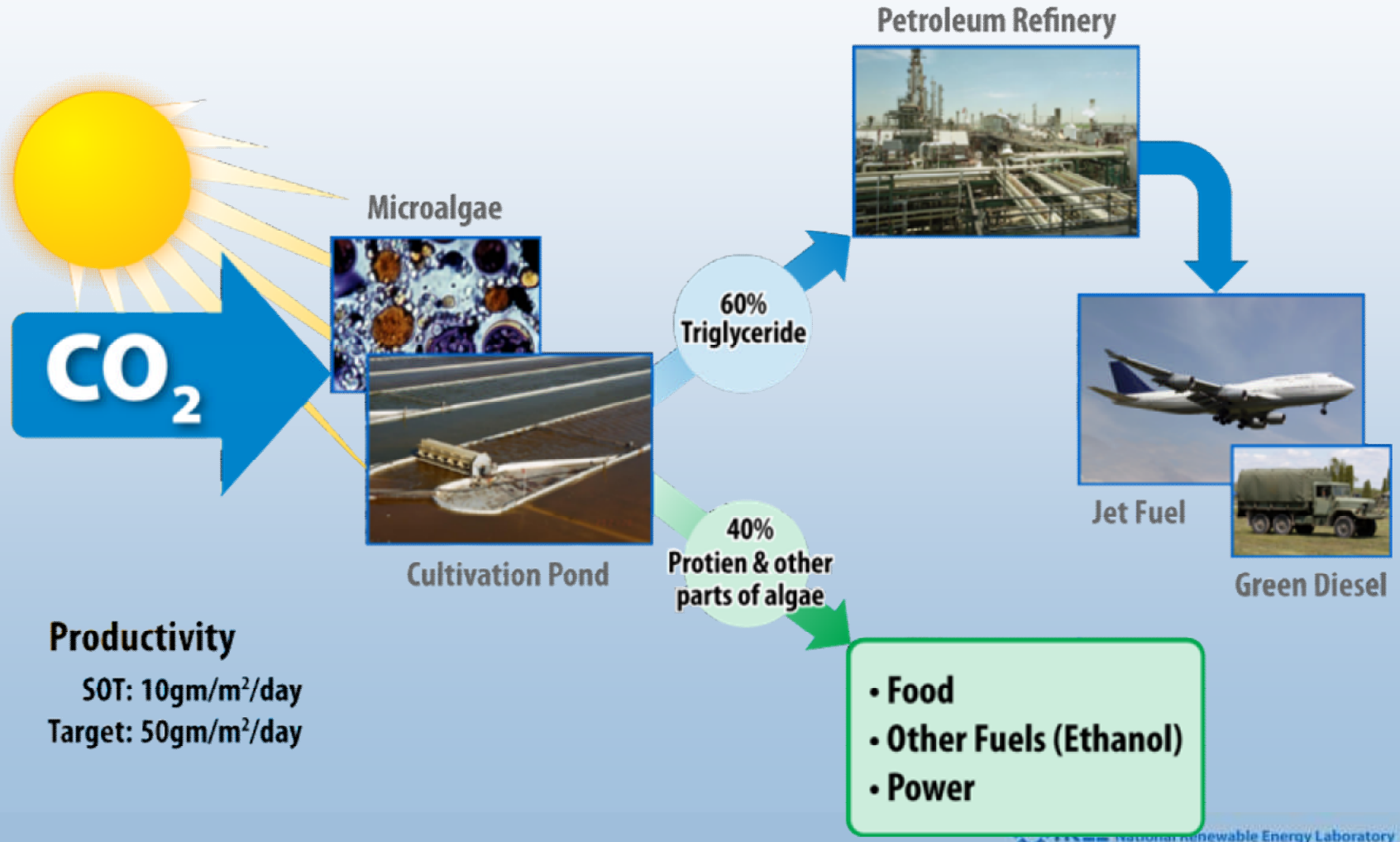
DOD Fuel Consumption



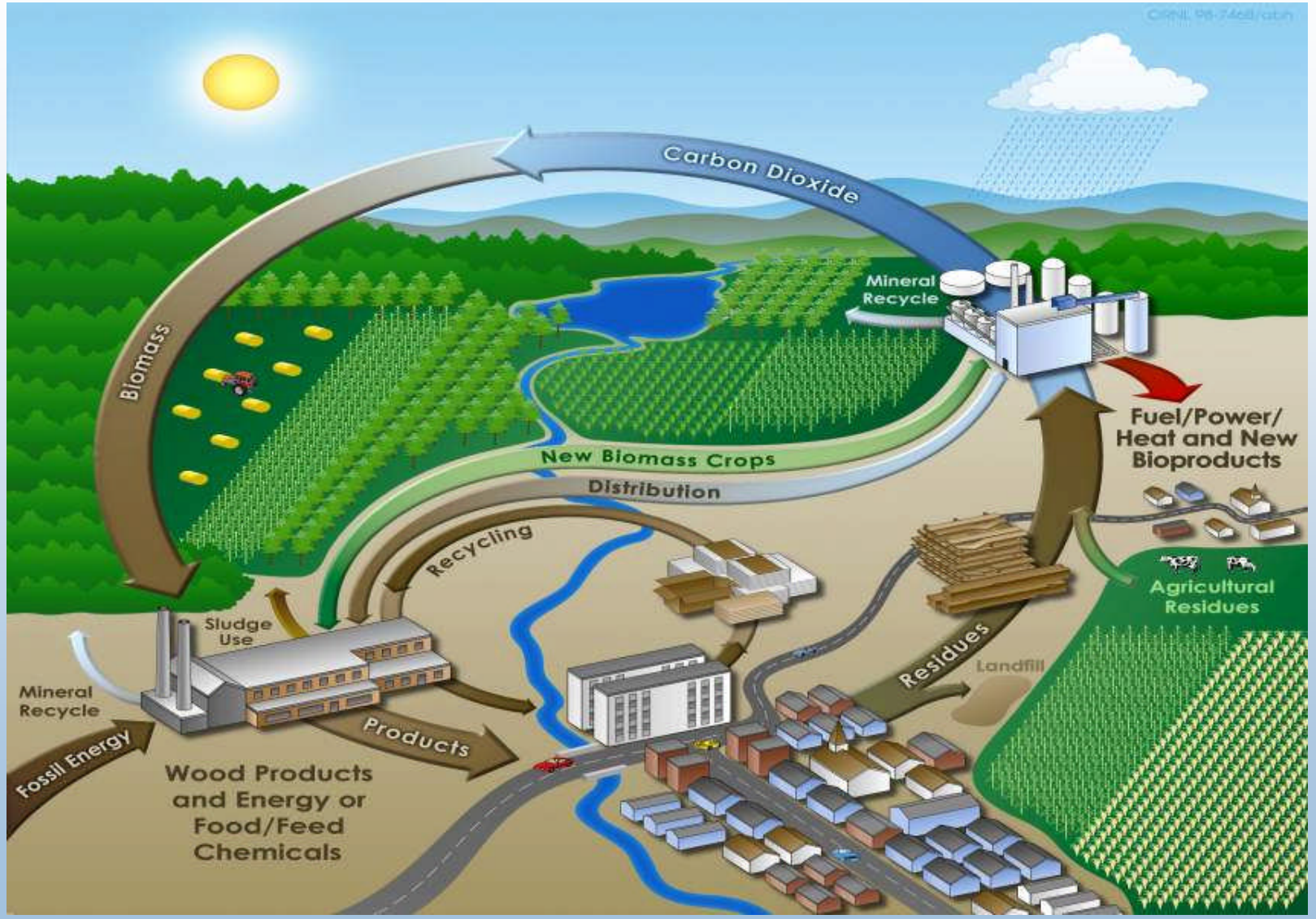
Source: Energy Security ITP, July 2006

A Novel Approach for making Jet Fuel From Biomass

Combine two technologies: Algae & Green Diesel



Biomass Carbon Cycle



Advanced Vehicles and Fuels Options

Conventional Vehicles

Hybrid Electric Vehicles

Plug-in Hybrid Vehicles

Hydrogen Vehicles—ICE or Fuel Cell

Corn Ethanol, Cellulosic Ethanol

Biodiesel, Fischer-Tropsch Diesel

Natural Gas other Petrochemicals

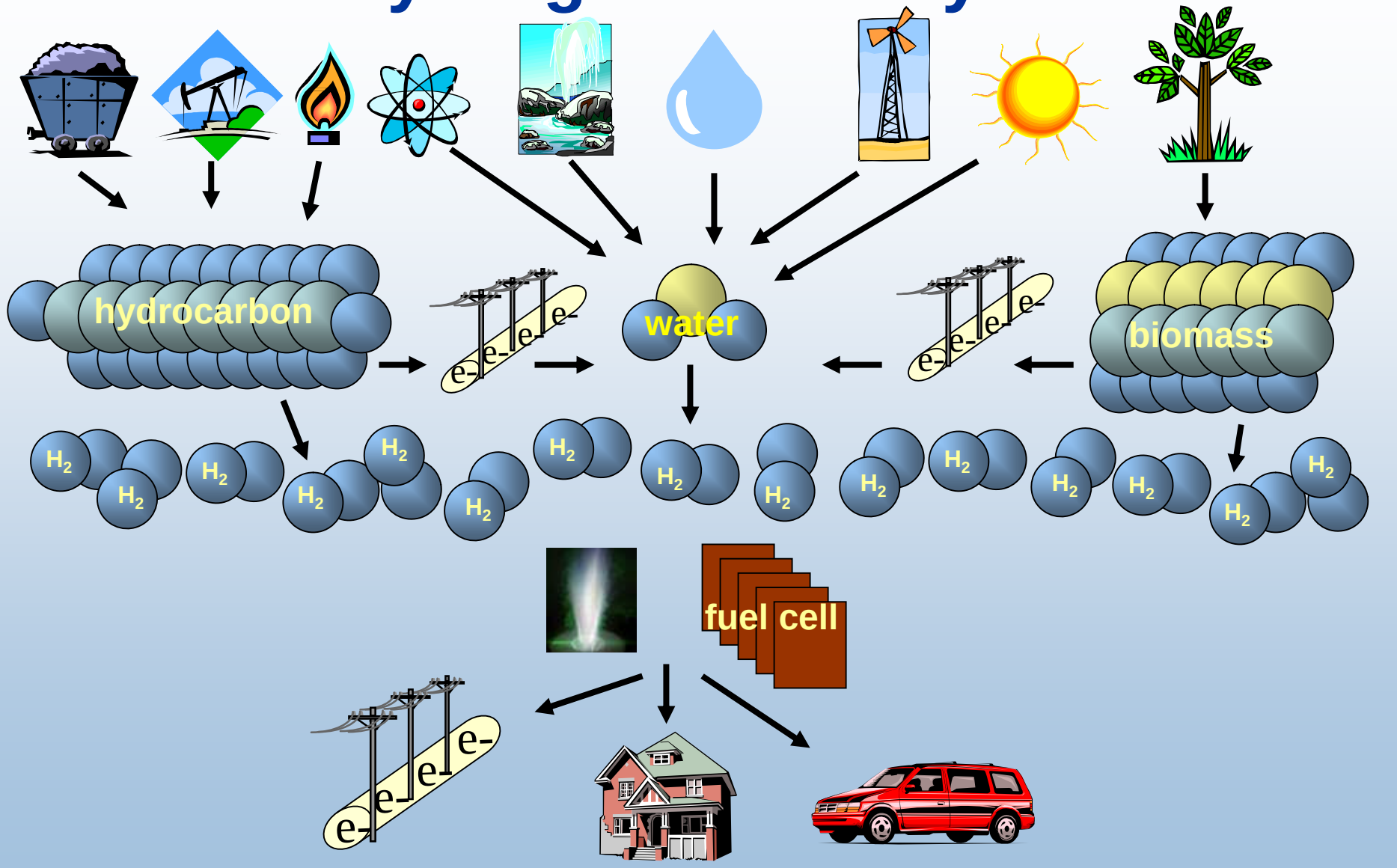
Electricity from Grid

Distributed Renewable Electricity

Hydrogen from Natural Gas

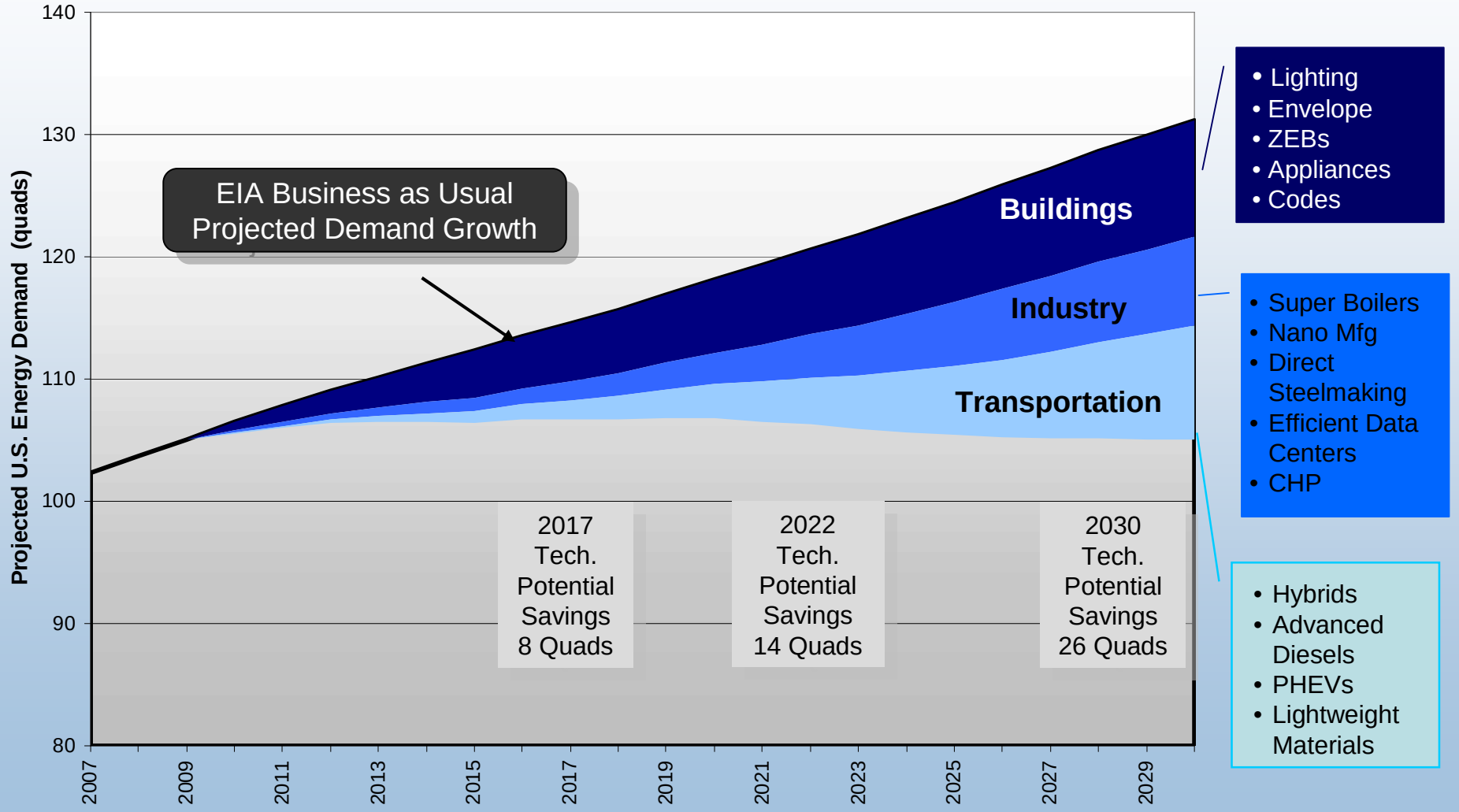
Renewable Hydrogen

Hydrogen Pathways



Hydrogen must be derived from other energy sources.

Energy Efficiency Has the Technical Potential to Level Energy Demand Growth



Source: DOE Scenario Projections

Energy Efficiency - Buildings

Van Geet home located in Idaho Springs, CO

08226

21st Century Performance home

12245

11269

NREL's Solar Energy Research Facility

10229

Solar Patriot House

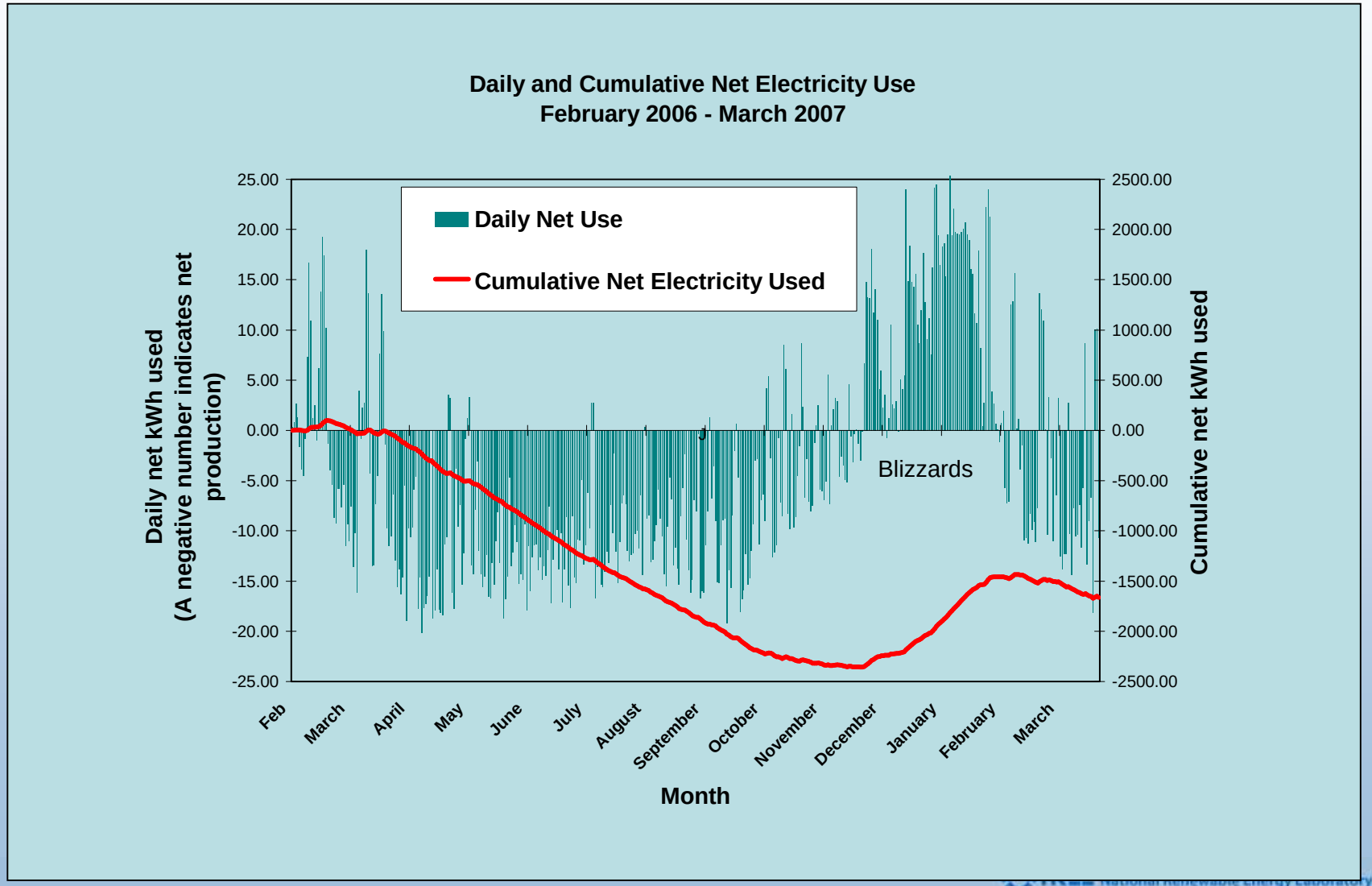
Zero Energy Buildings

- Commercial Sector Energy Use is Growing at 1.6% per year
- Need to think about ZERO to change trend
- Today's buildings mortgage the energy futures of this country

- The U.S. Department of Energy's (DOE) Building Technologies (BT) program set a goal of creating the conditions for low- and zero-energy commercial buildings (LZEBs) to be market viable by 2025.

Low-Cost ZEB Housing

Habitat for Humanity Energy Performance



Prioritization for Energy Efficiency

- **Technology**
  - Continue fundamental and applied R&D for enabling technologies to reduce the energy consumption and transform carbon footprint of the built environment (homes, offices, and manufacturing)
- **Regulation, Codes, Standards**
  - Accelerate, modernize and elevate appliance standards with greater consensus rulemakings
  - Promote superior model building codes with executable plan of coordinated implementation by the States
  - Provide utilities with returns on energy efficiency comparable or superior to investments in generation; provide industry with pathway for best practices
- **Voluntary and Market based Deployment**
  - Establishment of the National Action Plan for Energy Efficiency
  - Expand and Modernize Energy Star program concurrent w technology
  - Expand advocacy for energy efficient lighting (e.g., CFLs, LEDs)
  - Target civic infrastructure (e.g., Energy Smart schools, hospitals, libraries, municipal facilities) to be energy efficient, secure sites for distributed generation
- **Education and Outreach**
  - Multi-generational Education, targeted population, superior communications and behavioral modification

Efficiency Solutions – Buildings

- Transforming the carbon footprint of the built environment through zero energy buildings.
  - Continuing fundamental and applied R&D for enabling technologies, such as solid state lighting and advanced windows;
  - Accelerating and elevating codes and appliance standards;
  - Expanding and modernizing ENERGY STAR® program; and
  - Targeting the civic infrastructure (e.g., schools, hospitals, libraries, municipal facilities) to invest in Energy Smart solutions.

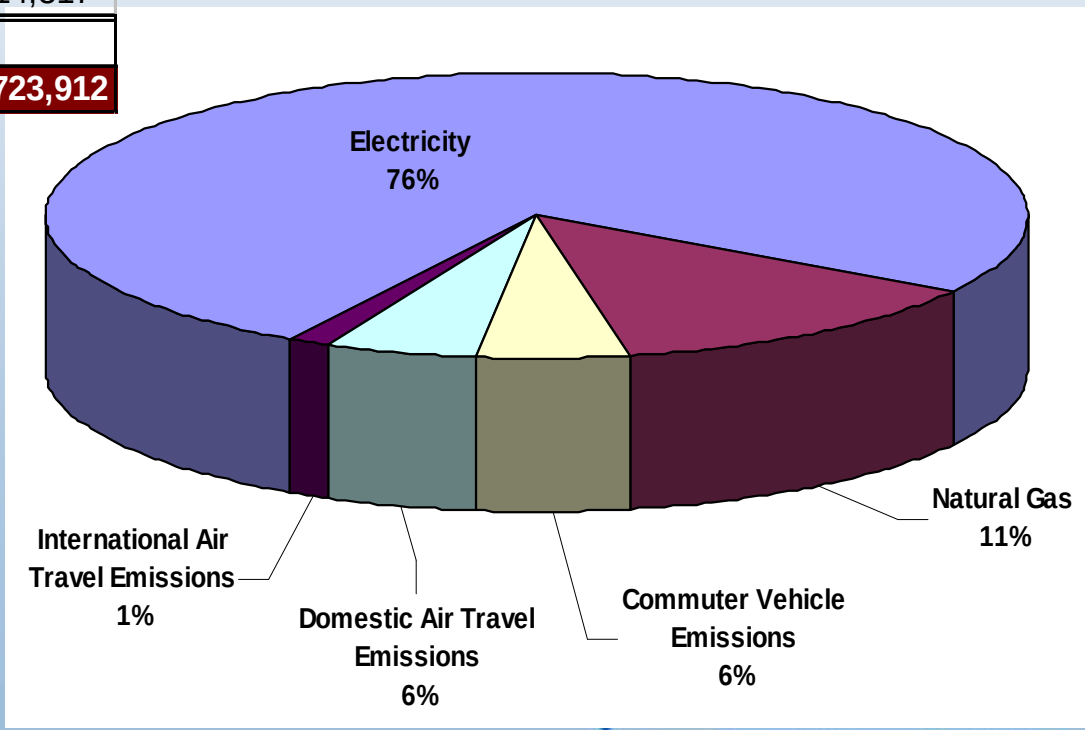
Science & Technology Facility

- LEED Platinum (certified in 2007)
- Platinum status
  - First federal building
  - One of 3 laboratory buildings
  - One of a total of 29 buildings

NREL Carbon Foot Print

SOURCE	Kg CO2 Eq.
Electricity	25,376,679
Natural Gas	**4,387,694**
Commuter Vehicle Emissions	1,677,026
Domestic Air Travel Emissions	**1,670,191**
International Air Travel Emissions	448,001
Fleet Vehicle Emissions	**90,838**
Solid Waste Disposal	42,044
Water (Electricity consumed)	**16,923**
Water (Natural Gas consumed)	14,517
	33,723,912

FY07 CO_2 Emissions Breakdown



NREL Achieving “Carbon Neutrality”

- NREL achieved carbon neutrality in all operations beginning in FY06
  - On-site renewable energy
  - New construction LEED Platinum (RSF Net Zero Energy)
  - Energy retrofits
  - Purchase of renewable energy credits (RECs) necessary to achieve “carbon neutrality”

Renewable Communities Involve All Technologies

Transportation | Solar | Wind

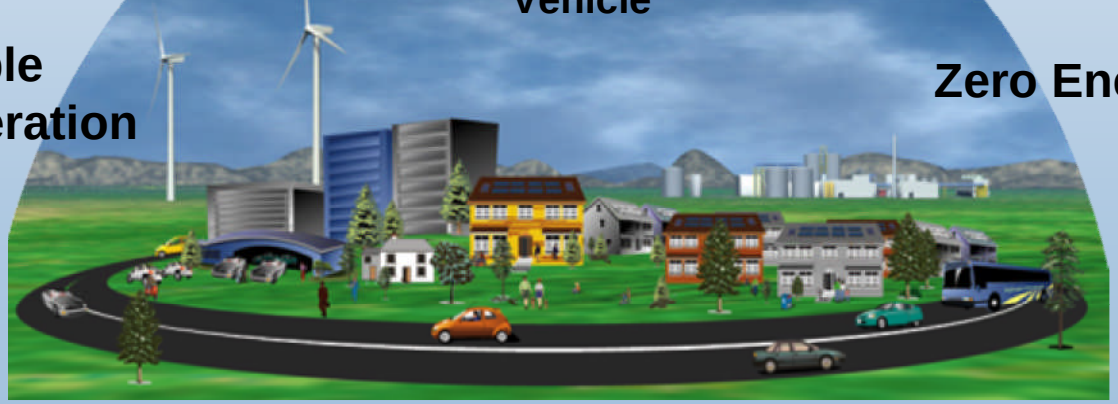
Electric Systems | Buildings | Biomass

Energy Storage | Energy Analysis

Plug-In Hybrid Electric Vehicle

Renewable Electric Generation

Zero Energy Buildings



Renewable Community


The U.S. Department of Energy's
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